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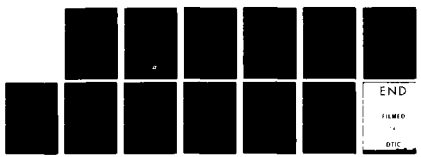

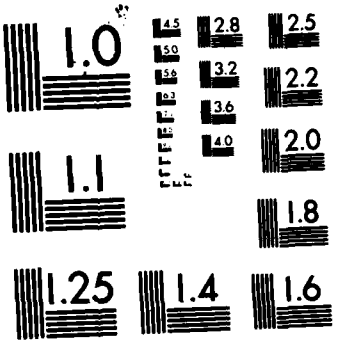

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Specification of the Transmitted Signal of the U.S. Marine Radiobeacon System

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January 1983
Final Report

U.S. Department of Transportation
United States Coast Guard

Office of Navigation
Washington DC 20593

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16. Abstract

This report documents the specification of the transmitted signal of the U.S. Marine Radiobeacon System. It is intended as a reference document consisting of specifications, definitions, and explanations for general use by designers, manufacturers, and users of this system.

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PREFACE

In July 1981, a set of signal specifications was published for the LORAN-C radionavigation system. The development of these specifications was restricted to the characteristics of the LORAN-C signal at the transmitter; however certain characteristics of the overall system were considered. The experience gained in the development of the LORAN-C signal specifications identified the need for a similar set of specifications for the U.S. Marine Radiobeacon System. Those specifications are reported herein.

METRIC CONVERSION FACTORS

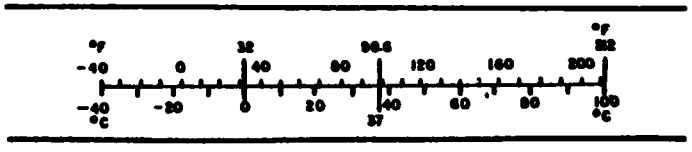
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

The U.S. Marine Radiobeacon System is a key element in both the Department of Transportation (DOT) and the Department of Defense (DOD) plans for navigation. This system is operated and maintained by the U.S. Coast Guard to provide accurate radionavigation service to users in the coastal navigation zones of the United States and in the Great Lakes. This specification defines the services provided in terms of the transmitted signal.

1.1 PURPOSE

This specification provides a technical description of the U.S. Marine Radiobeacon System signal at the transmitting stations. It is intended as a reference document consisting of specifications, definitions, and explanations for general distribution to designers, manufacturers, and users of this system.

1.2 SCOPE

This specification is restricted to the operational transmitted signal; however, other aspects of the system are discussed for information purposes. Section 2.0 provides general background information on the Radiobeacon System. The transmitted signal specification is presented in Section 3.0. Parameters that affect system usage are discussed in Section 4.0 and relevant definitions are given in Section 5.0.

2.0 RADIOBEACON INFORMATION

Basic descriptions and explanations of the U.S. Marine Radiobeacon System and its elements and characteristics are presented here as introductory material prior to the definition of the transmitted signal specification itself. That specification is defined in Section 3.0.

2.1 OVERVIEW

The U.S. Marine Radiobeacon System is an aid to navigation operated by the U.S. Coast Guard under the authority of Title 14 USC 81 (1). Each radiobeacon transmits a distinctive continuous carrier, keyed tone, radio signal at an assigned frequency in the band 285-325 kHz. These signals enable mariners to take bearings by means of shipboard radio direction finders. Such bearings are generally accurate to two degrees or less, depending on the equipment used and the skill of the operator.

Short range radiobeacons, nominally 10 nautical miles (NM) in range, are located in harbors, in waterways, and at harbor entrances. Radiobeacons of intermediate range, nominally 50 NM in range, constitute the majority of the system and are located to meet the requirements for harbor approach and for coastal and Great Lakes navigation. Longer range radiobeacons, 100 NM or more in range, are installed at a few widely separated locations of strategic importance to navigation, such as at significant landfalls. The Radiobeacon System is configured such that a vessel engaged in coastal navigation about the United States or on the Great Lakes will always be within range of at least one and most probably two or more radiobeacons. Geographic locations of Marine Radiobeacons and their assigned characteristics, operating frequencies, and service ranges may be obtained from the following sources:

1) Coast Guard Light Lists (CG 158-162); available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

2) Defense Mapping Agency Hydrographic/Topographic Center Publication 117 (Radionavigation Aids); available from the Defense Mapping Agency, Topographic Center, 6500 Brooks Lane, Washington, DC 20315.

3) Nautical Charts; available from the National Oceanic and Atmospheric Administration, National Ocean Survey (C-44), Riverdale, MD 20840.

Changes in operation, outages, and scheduled alterations are announced in Local Notices to Mariners which are available from local Coast Guard District Commanders.

2.2 RADIOBEACON EQUIPMENT

Radiobeacon equipment consists, basically, of transmitting and antenna sub-systems. The transmitter, with its associated coder and keyer, generates a radio frequency (RF) signal on a specified frequency in the Marine Radiobeacon band (285-325 kHz). This signal consists of two separate carrier frequencies, a continuous carrier at the assigned operating frequency and a coding, or modulating, carrier 1020 Hz higher in frequency. The radiobeacon identifying characteristic is created by keying the higher frequency. The U.S. Marine Radiobeacon System uses transmitters of common solid state design with three power level options designated as follows:

TRANSMITTER MODEL NO.	POWER
CDWQ-NX 250 BD	62.5 Watts
CDWQ-NX 1000 BD	250 Watts
CDWQ-NX 4000 BD	1000 Watts

The antenna, with its associated ground plane and coupling and tuning equipment, radiates the radiobeacon signal in an omindirectional pattern. Marine Radiobeacon antennas, typically 35 to 125 feet in height, are physically short in comparison to the signal wavelength which averages 1000 meters (3280 feet). These antennas are very sensitive to atmospherics, the presence of salt spray, or wind induced tilt. An antenna tuning unit is provided to automatically maintain the electrical properties of the antenna in the presence of such disturbances. Three models, which are matched to the appropriate transmitter power level, are in service:

TUNER MODEL NO.	POWER
NX 400 TUB	62.5 Watts
NX 2000 TUB	250 Watts
NX 4000 TUB	1000 Watts

2.3 MODES OF OPERATION

Radiobeacons operated by the Coast Guard are designated as either sequenced or continuous. A sequenced radiobeacon operates on the same frequency with a group of up to five other radiobeacons located in the same geographical area. Each beacon normally transmits its signal for one minute out of each six minute period around the clock in sequence with the other beacons in the group. If less than six radiobeacons are included in a group, one or more of them may transmit for two of

the six one-minute periods. A continuous radiobeacon operates continually, every minute of every hour, not sharing its radio frequency with any other station within its operating range.

Special calibration radiobeacons of short range capability broadcast in clear weather to enable vessels to swing ship for the purpose of calibrating their radio direction finders. These calibration stations operate only on advance request to the Commander of the Coast Guard District in which the calibration station is located.

Further information concerning the operational characteristics of individual radiobeacons may be obtained from the Coast Guard Light Lists.

2.4 ADVERTISED SERVICE RANGE

The advertised service range of a radiobeacon is the range at which it will provide a prescribed field intensity level to the user. The prescribed field intensities for U.S. Marine Radiobeacon signals, established by international agreement, are as follows:

50 microvolts per meter for radiobeacons north of $40^{\circ}N$
75 microvolts per meter for radiobeacons between $40^{\circ}N$ and $31^{\circ}N$
100 microvolts per meter for radiobeacons south of $31^{\circ}N$

2.5 PROTECTION RATIO

Service provided by radiobeacons must be protected from intrasystem interference. This has been achieved by designing and operating the system such that, for any radiobeacon considered, the signal intensity at its advertised range will be stronger than those from other radiobeacons. The difference between desired and undesired signal strengths, expressed as a ratio in decibels (dB) is known as the "protection ratio". The system is operated to ensure a protection ratio of 15 dB for sequenced and continuous radiobeacons, 22 dB for calibration radiobeacons, and 28 dB with respect to Canadian radiobeacons.

2.6 CALIBRATION

Radiobeacons are calibrated upon establishment. Field strength measurements are conducted and appropriate adjustments are made to the beacon equipment periodically on a routine basis. Radiobeacons are re-calibrated whenever there are major alterations to radiobeacon equipment or to surrounding structures or when there is data to indicate the existance of deviations from the desired transmitted signal.

2.7 FAILURE MODES

The low power transmitter (CDWQ-NX 250 BD, 62.5 Watts) uses a single power amplifier to provide the required signal. A redundant amplifer and duplicate keyers are provided within that transmitter. Provision has been made for automatic switching between duplicated equipment to ensure continuity of service in the case of failure or malfunction.

The medium and high power transmitters (CDWQ-NX 1000 BD, 250 Watts and CDWQ-NW 4000 BD, 1000 Watts) also contain dual keyers and use ganged low

power amplifiers, identical to that of the model CDWQ-NX 250 BD transmitter, to generate the desired output level. The medium power unit uses 4 amplifiers while the high power unit uses 16. There are no redundant amplifier configurations for the medium and high power transmitters. Automatic switching is provided in case of keyer failure. Should one or more amplifiers fail, however, the beacon will continue to transmit but at a reduced power level, losing 62.5 Watts per amplifier failure. A Notice to Mariners shall be published when output power drops 3 dB.

3.0 RADIOBEACON TRANSMITTED SIGNAL SPECIFICATION

The characteristics of the U.S. Marine Radiobeacon System transmitted signal are specified in the following sub-paragraphs. These specifications are summarized in Table I. All U.S. Marine Radiobeacons shall conform to these specifications except that, in the event of discrepancies between this specification and the Aids to Navigation Manual, Radionavigation (CG-222-4), that Manual shall take precedence.

3.1 GENERAL

Operational characteristics of individual Marine Radiobeacons, such as frequency, characteristic, service range, and sequence, when applicable, shall conform to those published in the Coast Guard Light Lists as amended by Notices to Mariners where appropriate.

3.2 FREQUENCY

The frequency band 285-325 kHz has been established by the International Telecommunications Union for marine radionavigation in the Western Hemisphere. All U.S. Marine Radiobeacons shall operate within this band.

3.2.1 Frequency Control and Tolerance

All Coast Guard operated radiobeacons shall maintain their radio frequency by use of quartz crystal units. By international agreement, all Marine Radiobeacon stations shall maintain a frequency tolerance within $\pm$ 0.01% of their assigned frequency.

3.3 EMISSIONS

All Marine Radiobeacons in the United States shall transmit type H2A, tone modulated continuous wave (CW), dual-carrier signals. One carrier shall operate continuously at the assigned station frequency and a coding, or modulating, carrier shall operate 1020 Hz $\pm$ 50 Hz higher in frequency.

3.3.1 Modulation

The radiobeacon identifying characteristics shall be created by keying the higher carrier frequency. Modulation percentage shall be determined by the power ratio of the two carriers. U.S. Marine Radiobeacons shall operate at a 70% $\pm$ 5% modulation level.

TABLE I

SUMMARY OF RADIOBEACON SIGNAL SPECIFICATIONS

FREQUENCY BAND	285-325 kHz
FREQUENCY CONTROL	CRYSTAL
FREQUENCY TOLERANCE	± 0.01% of assigned frequency
TYPE OF EMISSION	Type H2A (tone modulated CW)
MODULATION	TYPE: keyed upper sideband separated from carrier by 1020 Hz LEVEL: 70% ± 5%
SPURIOUS EMISSIONS	As low as practicable compliant with FCC Rules and Regulations Parts 81 and 87
CODE CONTENT	1, 2, or 3 International Morse characters
CHARACTERISTIC KEYING	
Rate	10 words/minute, nominal
Dot Element Length	0.125 seconds
Dash Element Length	0.375 seconds
Interval between Elements	0.125 seconds
Interval between Characters	0.375 seconds
Interval between Characteristics	0.625 seconds
OPERATING CYCLE	50 second coded period followed by a 10 second dash
MODE OF OPERATION	Continuous - operating cycle repeated every minute Sequenced - operating cycle repeated one minute out of each 6 minute period for a six beacon grouping Calibration - continuous upon advance notice
SIGNAL STRENGTH AT ADVERTISED RANGE	50 microvolts/meter north of 40°N 75 microvolts/meter between 40°N and 31°N 100 microvolts/meter south of 31°N
GEOGRAPHIC COVERAGE	Coastal navigation zones and Great Lakes

3.3.2 Spurious Emissions

Spurious emissions shall be at the lowest level practicable, in compliance with FCC Rules and Regulations, Parts 81 and 87.

3.4 STATION CHARACTERISTICS

The characteristics assigned to radiobeacon stations in the United States shall be limited to combinations of one, two, or three International Morse Code characters.

3.4.1 Keying

Characteristic signals shall be sent at true morse dot/dash spacing ratios (1:3) at a nominal rate of 10 words per minute (WPM). The basic code element (bit) shall be a dot of 125 millisec (ms) duration. The dash shall be 375 ms in length (3 bits). The interval between elements (dots and/or dashes) shall be 125 ms (1 bit). The interval between code characters shall be 375 ms (3 bits). The interval between station characteristic repetition shall be 625 ms (5 bits).

3.4.2 Operating Cycle

During each minute of operation, the station characteristic shall be repeated continuously for 50 seconds followed by a 10 second dash.

3.5 MODES OF OPERATION

All U.S. Marine Radiobeacons, other than calibration radiobeacons, shall operate 24 hours per day in either a continuous or sequenced mode of operation.

3.5.1 Continuous Radiobeacons

Continuous radiobeacons shall repeat their operating cycle every minute without interruption.

3.5.2 Sequenced Radiobeacons

Sequenced radiobeacons shall be arranged in groups of up to six, operating on a common frequency in the same geographic area. Each beacon shall transmit its signal for one minute out of each six minute period throughout the day. If less than six radiobeacons are included in a group, one or more of them shall transmit for two of the six one-minute periods as necessary to provide transmissions throughout the six minute period.

3.5.3 Calibration Radiobeacons

Calibration radiobeacons shall operate upon advance request and shall provide a continuous tone modulated CW signal for the purpose of calibrating shipborne radio direction finding equipment. Calibration radiobeacons shall have a reliable range of 5 NM. The assigned characteristic shall be transmitted twice followed by a 20 second dash. The complete sequence shall be repeated twice each minute.

3.6 SIGNAL STRENGTH

Each radiobeacon shall provide a prescribed signal level at the limits of its advertised service range. The prescribed field intensities for the U.S. Marine Radiobeacon System are:

50 microvolts per meter for radiobeacons north of 40°N
75 microvolts per meter for radiobeacons between 40°N and 31°N
100 microvolts per meter for radiobeacons south of 31°N

3.6.1 Field Intensity Requirements

The field intensity levels specified in Table II shall be provided to ensure that the proper radiobeacon signal level is available at the limit of the advertised service range.

3.6.2 Protection Ratio

The protection ratio for continuous and sequenced radiobeacons shall be 15 dB except for Canadian stations which under international agreement are afforded 28 dB protection. The protection ratio for calibration radiobeacons shall be 22 dB.

3.7 GEOGRAPHIC COVERAGE

The U.S. Marine Radiobeacon System shall be so configured that a vessel engaged in coastal navigation or in the Great Lakes will always be within range of at least one and preferably two or more radiobeacon signals.

3.8 CONFORMANCE

All U.S. Marine Radiobeacons shall be calibrated upon establishment. Field strength measurments shall be conducted periodically thereafter on a routine basis to ensure conformance to the specification presented herein. Radiobeacons shall be re-calibrated whenever there are major alterations to radiobeacon equipment or to surrounding structures or when there is data to indicate deviations from these specifications.

4.0 USER CONSIDERATIONS

Some of the more pertinent factors which should be considered by the users of the U.S. Marine Radiobeacons Systems are discussed briefly in this section.

4.1 VESSEL INDUCED ERROR

The direction of travel of a radio wave is changed as it passes through electromagnetic fields. Such fields exist in the presence of metallic objects. Many vessels exhibit certain electromagnetic field characteristics because they are constructed of metal and most employ rigging, masts, and other items of a metallic nature. The radio direction finder antenna should be located as clear of these fields as possible. Unfortunately, all the electromagnetic influences of a vessel cannot be avoided. Therefore, the mariner must somehow consider them when taking radio bearings. The most effective way to accomplish this is to calibrate the radio direction finder after installation and to verify its accuracy from time to time, and especially whenever structural changes to a vessel occur.

TABLE II.

FIELD INTENSITY REQUIREMENTS

ADVERTISED RANGE (Mi)*	REQUIRED INTENSITY AT ONE MILE* IN MICROVOLTS PER METER			
	SEA WATER			GREAT LAKES
	50 μV/m	75 μV/m	100 μV/m	
10	500	750	1000	550
15	750	1125	1500	800
20	1000	1500	2000	1100
25	1300	1950	2600	1450
30	1500	2250	3000	1800
35	1800	2700	3600	2150
40	2100	3150	4200	2550
45	2400	3600	4800	2950
50	2700	4050	5400	3400
55	3000	4500	6000	
60	3300	4950	6600	4350
65	3600	5400	7200	
70	3900	5850	7800	5400
75	4200	6300	8400	
80	4500	6750	9000	6600
85	4900	7350	9800	
90	5300	7950	10600	7850
95	5600	8400	11200	
100	6000	9000	12000	9300
110	6800	10200	13600	
120	7600	11400	15200	
130	8400	12600	16800	
140	9300	13950	18600	
150	10400	15600	20800	
160	11500	17250	23000	
170	12600	18900	25200	
180	13800	20700	27600	
190	15100	22650	30200	
200	16600	24900	33200	
250	25100	37650	50200	
300	37500	56250	75000	
350	54900	82350	109800	

*Nautical Miles for Sea Water
Statute Miles for Great Lakes

In order to facilitate radio direction finder calibration, the Coast Guard operates and maintains calibration stations which provide their services on special request. Calibration is accomplished by comparing visual bearings to radio bearings, recording the difference and preparing a calibration curve. This curve should be posted so that the navigator can conveniently apply corrections to radio bearings.

4.2 MERCATOR ERROR

The signal transmitted by a radiobeacon follows a great circle course. Radio bearings may be plotted directly on a Mercator chart if the distance to the beacon is less than 50 NM or if the distance in longitude involved is not in excess of two degrees. When these measures are exceeded a correction should be applied. Corrections are published in Defense Mapping Agency Hydrographic/Topographic Center Publication 117, Radionavigational Aids.

4.3 FIX

A bearing from a radiobeacon may be combined with bearing information from other radiobeacons or from other sources, such as a line of position from an astronomical or LORAN observation, to locate (fix) the position of the vessel.

The position of a vessel may be estimated from radio bearings on a single radiobeacon by taking successive bearings on the station with intervening periods of time and plotting these with respect to the distance and course run between the times the bearings are taken. Though a position so obtained is often referred to as a "running fix" it is not a fix and should be used with caution.

4.4 HOMING

A radiobeacon may be used as a leading mark for which to steer directly. The navigator can correct the course from time to time using successive radio bearings. Such a signal off a harbor entrance or other objective may be approached with certainty from a considerable distance. Following a signal to its source is referred to as "homing". This procedure should be practiced with caution. The navigator must be sure that the origin of the signal is of sufficient distance to avoid grounding or collision.

4.5 RECIPROCAL BEARINGS

It is of extreme importance to avoid the use of reciprocal bearings (180° ambiguity). The mariner homing on a reciprocal bearing may be far at sea before discovering this error. Likewise, a radiobeacon fix obtained by using reciprocal bearings would provide false position information. The false position may indicate that the mariner is in safe waters while in fact an extremely hazardous situation may exist.

Ambiguity may be avoided when using a radio direction finder without a sense antenna by taking repeated radio bearings and observing the direction in which they tend to change. If the vessel is making forward way, successive bearings will move aft on the side of the vessel on which the radiobeacon lies.

5.0 DEFINITIONS

Definitions of words and phrases used in this specification are presented in this section.

Advertised Service Range: the range at which a radiobeacon signal provides a prescribed field intensity.

Aids to Navigation: any signal device external to a vessel specifically intended to assist a navigator to determine a position or safe course, or to warn of danger or obstructions to navigation.

Atmospherics: disturbances in radio reception produced by natural electric discharges (lightning).

Bearing: the horizontal direction of a line of sight between two objects.

Bit: basic radiobeacon code element (dot) length, 125 milliseconds.

Calibration Mode: continuous tone modulated continuous wave signal provided for the purpose of calibrating shipboard radio direction finding equipment.

Character: letter or number in the radiobeacon characteristic.

Characteristic: the identifying code transmitted by a radiobeacon

Coastal Navigation: navigation within 50 nautical miles from shore or the limit of the Continental Shelf (100 fathom curve), whichever is greater.

Code Cycle: coded information transmitted continuously for 50 seconds followed by a 10 second dash.

Continuous Mode: radiobeacon code cycle repeated continuously throughout the day.

Establish: to place a radiobeacon in operation for the first time.

Fathom: a unit of measure equal to 6 feet used mainly in measuring the depth of water.

Fix: a position determined from to bearing of two or more known points.

Prescribed Field Intensity: the field intensities prescribed for radiobeacon operation in the Western Hemisphere: 50 microvolts per meter north of 40° N, 75 microvolts per meter between 40° N and 31° N, 100 microvolts per meter south of 31°N.

Protection Ratio: the difference between desired and undesired signal strengths expressed as a ratio in decibels (dB). The protection ratio is 15 dB for continuous and sequenced radiobeacons, 22 dB for calibration radiobeacons, and 28 dB for Canadian radiobeacons.

Radiobeacon: electronic device which transmits a radio signal for use as an aid to navigation.

Sequenced Mode: code cycle information provided during the appropriate period of the sequenced cycle. Sequence cycle is repeated continuously.

Service Range: see advertised service range.

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